GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

CMS

III. Physikalisches Institut A

RWTH AACHEN UNIVERSITY

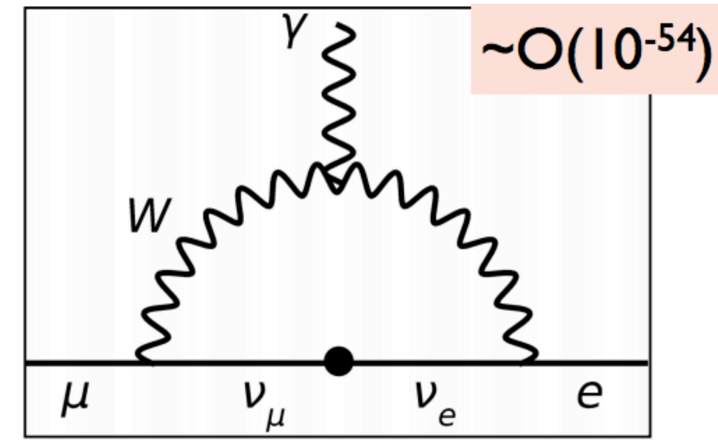
SEARCH FOR CHARGED LFV

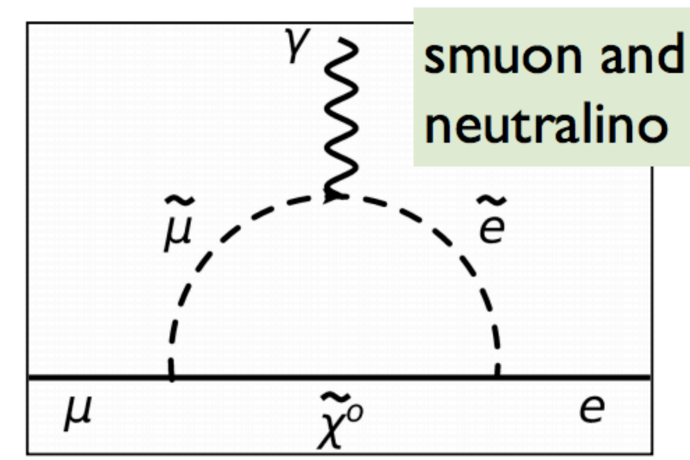
Swagata Mukherjee, on behalf of the CMS collaboration

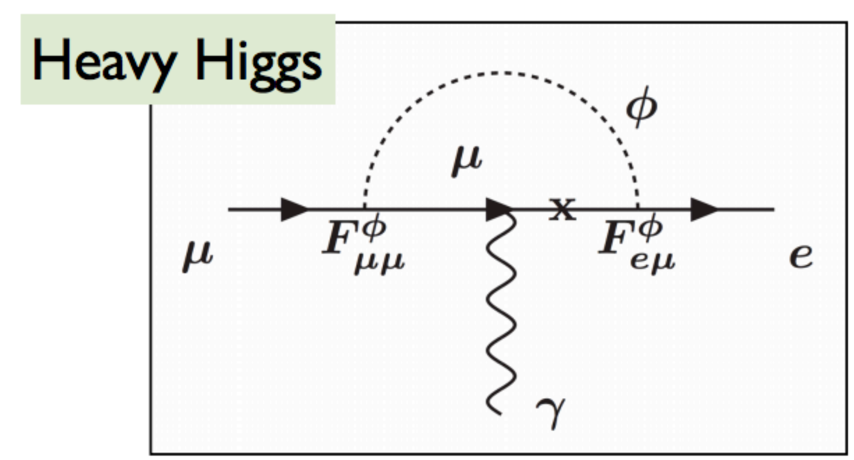
III. Physikalisches Institut A, RWTH Aachen University, Germany

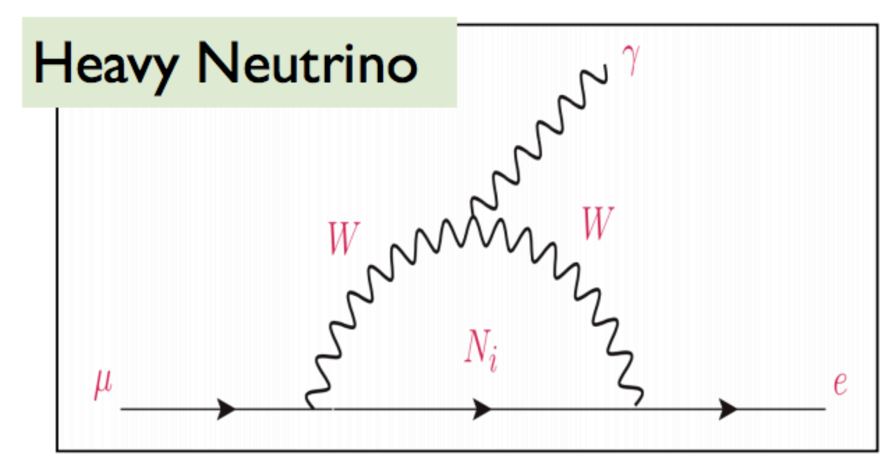
INTRODUCTION

- Neutral Lepton Flavour Violation (LFV) observed
  - neutrino oscillation
- Charged LFV not observed
  - Example would be μ→eɣ
  - Branching Ratio from known physics ~O(10-54)
  - Can be enhanced in presence of New Physics
  - Many extensions of SM with new states at TeV scale generates charged LFV









SEARCHES COVERED IN THIS TALK

I'm from CMS, and will show ATLAS results only when the corresponding CMS analysis is not yet public.

Final state	Interpretations	Dataset	Experiment
eμ	RPV, QBH, Z'	2016	CMS
eτ, μτ	RPV, QBH, Z'	2016	ATLAS
Multileption	Heavy fermions	2016	CMS

Strong limit from indirect searches in some cases.

Can be degraded by cancellation of LFV effects from other new physics.

Direct search is complementary to limits obtained from searches at lower energies.

HIGH MASS eμ SEARCH (CMS)

EXO-16-058, **JHEP 04 (2018) 073**, arXiv 1802.01122

Clean channel

Simple event selection

- **At least one electron and one muon in event, high-pT + isolated**
- **Choose the lepton pair with highest invariant mass**
- **Veto electrons which are close to a muon (to avoid muon faking electron due to brem of muon in ECAL)**

No explicit requirement on opposite sign lepton pair (charge misidentification rate increases with pT, as tracks bend less)

Main background: ttbar, could be reduced with b-jet veto

- Trade off between analysis sensitivity towards a particular model and being sensitive to many models.
- We (CMS) choose to stay as model independent as possible, so no other signal specific cuts applied

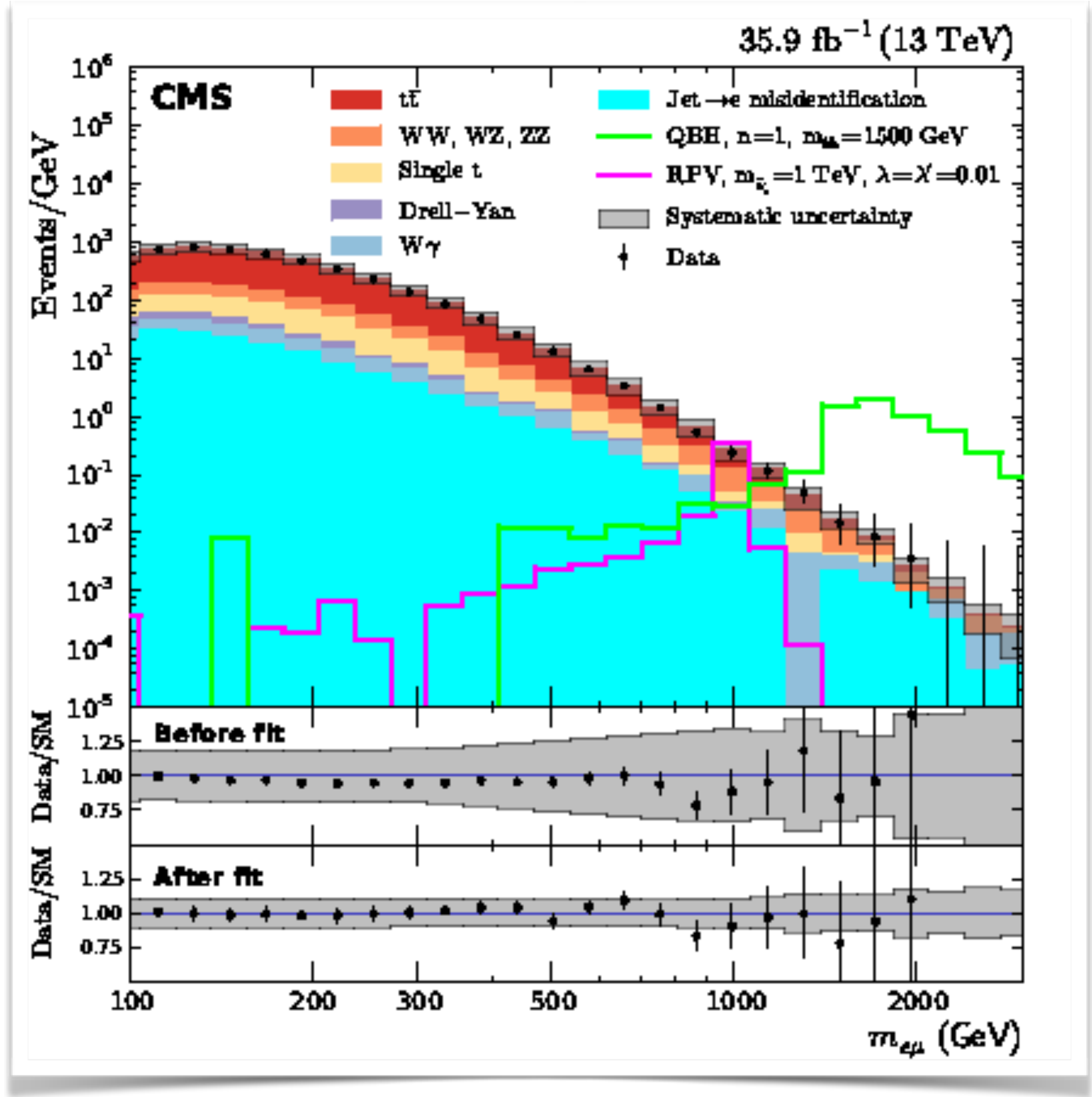
HIGH MASS eμ SEARCH (CMS)

EXO-16-058, **JHEP 04 (2018) 073**, arXiv 1802.01122

Background

Real lepton	**ttbar** **WW** single-top Drell-Yan WZ,ZZ
Fake lepton	Wγ W+Jets QCD

Jet mis-identified as electron (Data-driven)



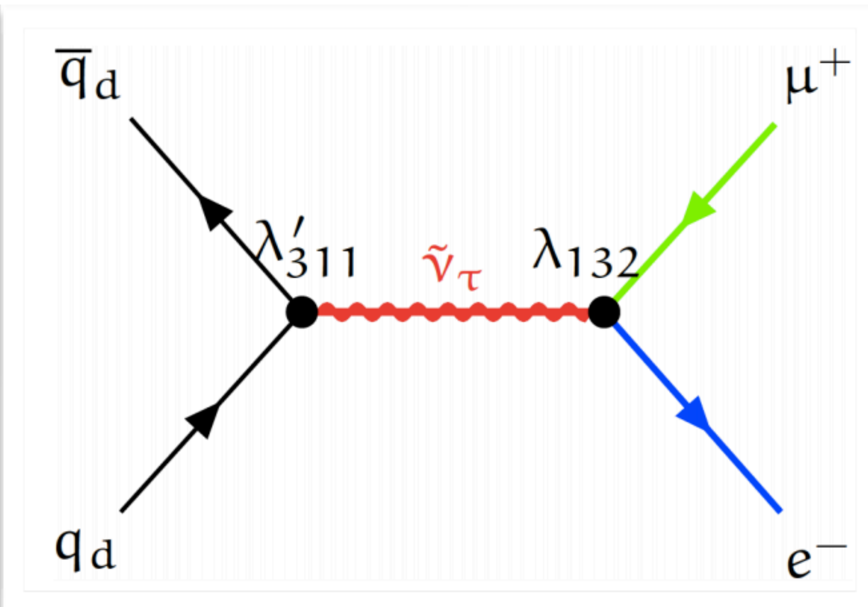
No significant excess

HIGH MASS eμ SEARCH (CMS)

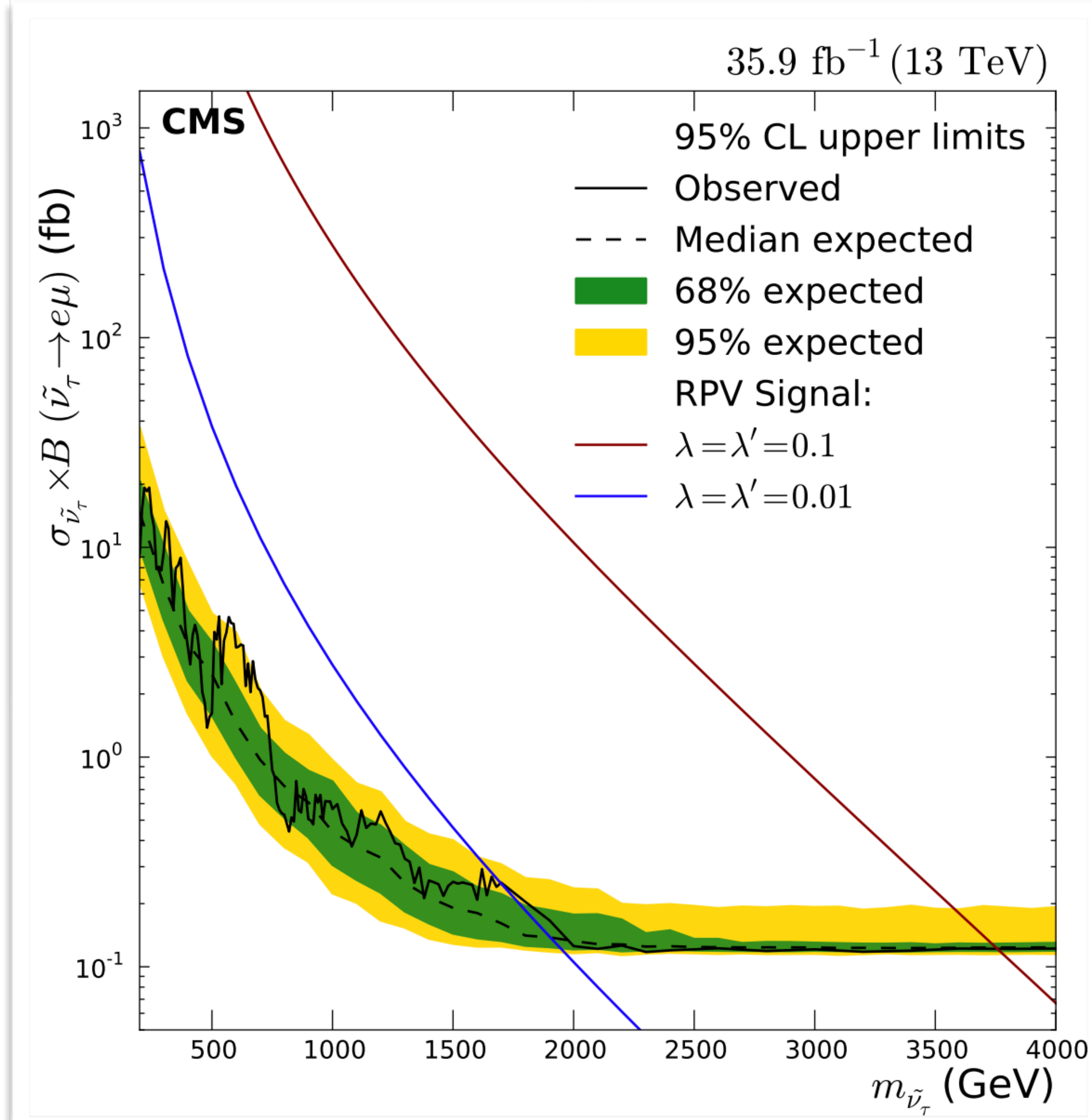
EXO-16-058, **JHEP 04 (2018) 073**, arXiv 1802.01122

RPV SUSY interpretation

- Resonant production of **τ** sneutrino Lightest SUSY Particle
- Assume all RPV couplings vanish, except λ'_{311}, λ_{132}, λ_{231}



Coupling	mass limit
λ'= λ=0.01	1.7 TeV
λ'= λ=0.1	3.8 TeV



Strong limits from low-energy muon conversion experiments

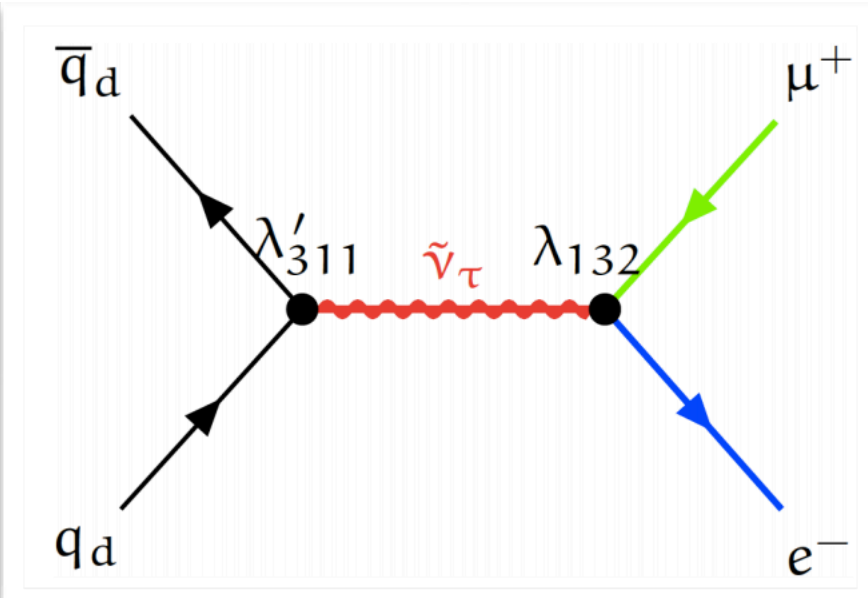
$\lambda_{132}\lambda'_{311} < 3.3 \times 10^{-7}\ (M_{\tilde{\nu}_\tau}/1\,\mathrm{TeV})^2$ at 90% CL

HIGH MASS eμ SEARCH (CMS)

EXO-16-058, **JHEP 04 (2018) 073**, arXiv 1802.01122

RPV SUSY interpretation

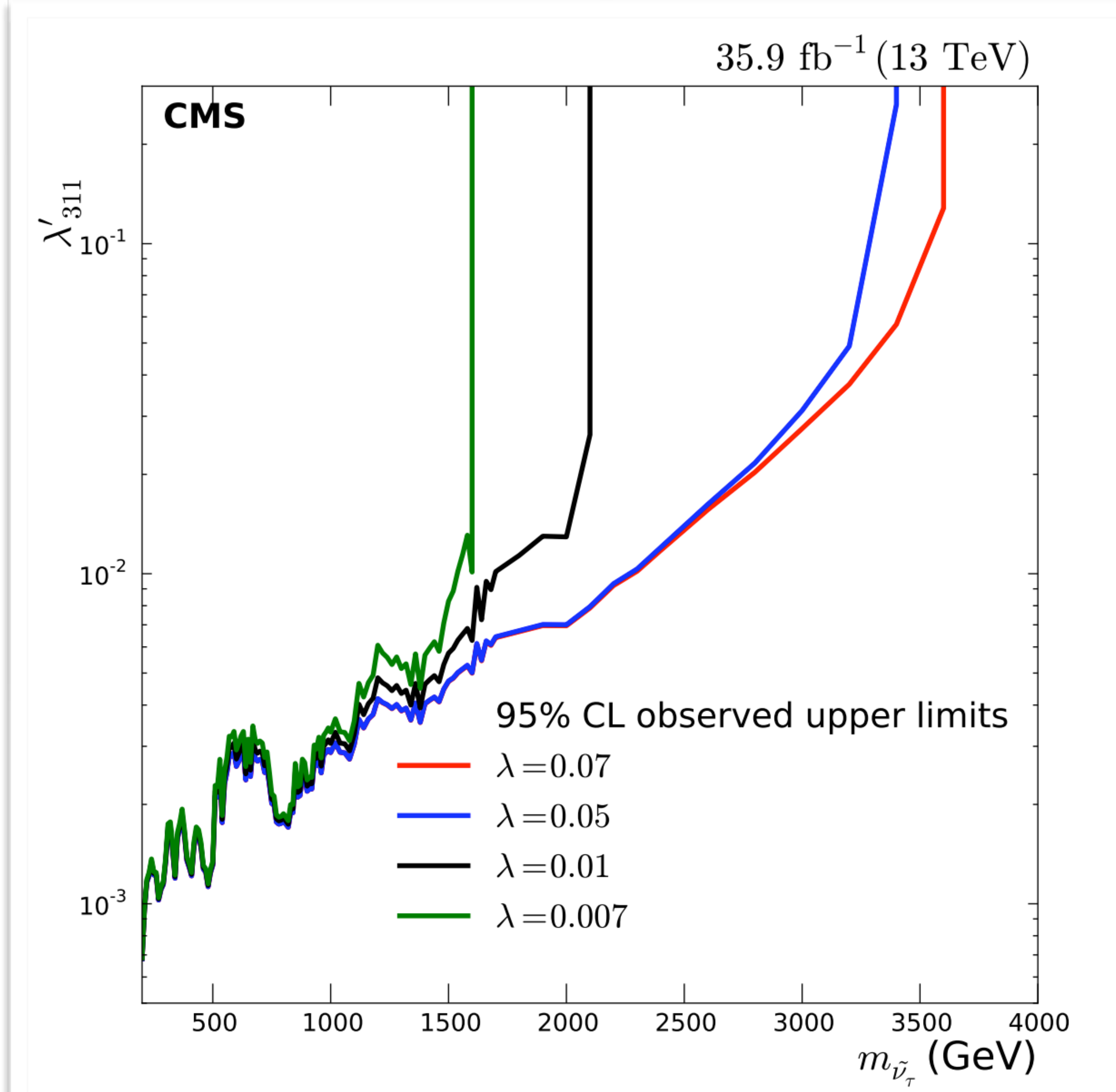
- Resonant production of **τ** sneutrino Lightest SUSY Particle
- Assume all RPV couplings vanish, except λ'_{311}, λ_{132}, λ_{231}



Coupling	mass limit
λ'= λ=0.01	1.7 TeV
λ'= λ=0.1	3.8 TeV

Strong limits from low-energy muon conversion experiments

$$\lambda_{132}\lambda'_{311} < 3.3 \times 10^{-7}\ (M_{\tilde{\nu}_\tau}/1\,\mathrm{TeV})^2 \text{ at 90\% CL}$$



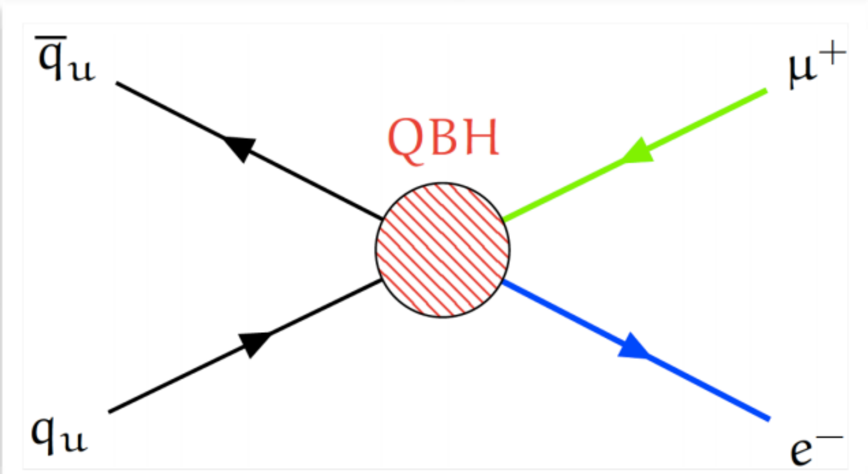
HIGH MASS eμ SEARCH (CMS)

EXO-16-058, **JHEP 04 (2018) 073**, arXiv 1802.01122

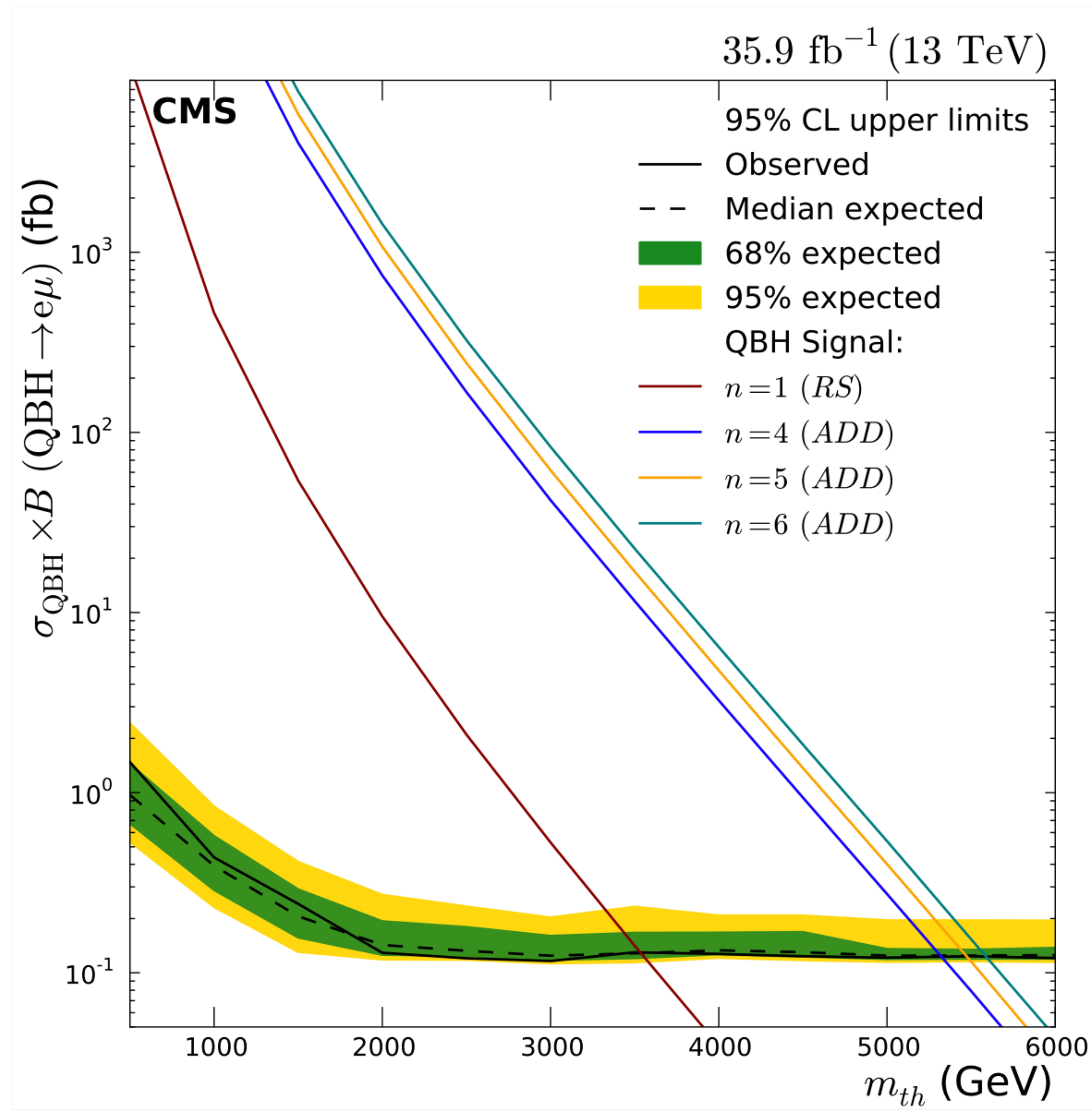
QBH generator by D. Gingrich arxiv 0911.5370

Quantum Blackhole (QBH)

- Extra dimension(s) → Fundamental Planck scale lowered to TeV region
- QBH produced if $\sqrt{s} > M_P$
- Spin-0, colorless, neutral QBH
- n=1 : RS model
- n=4,5,6 : ADD model



Extra dim.	mass limit
n=1	3.6 TeV
n=4	5.3 TeV
n=5	5.5 TeV
n=6	5.6 TeV



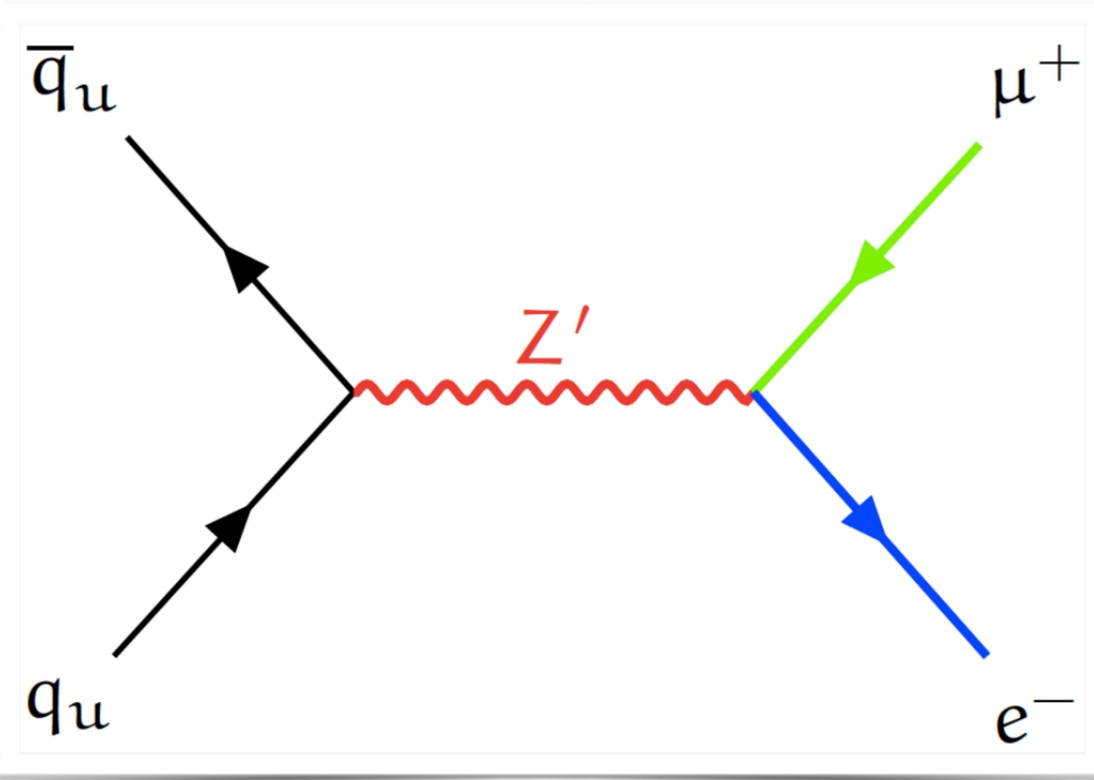
QCD color, electric charge conserved

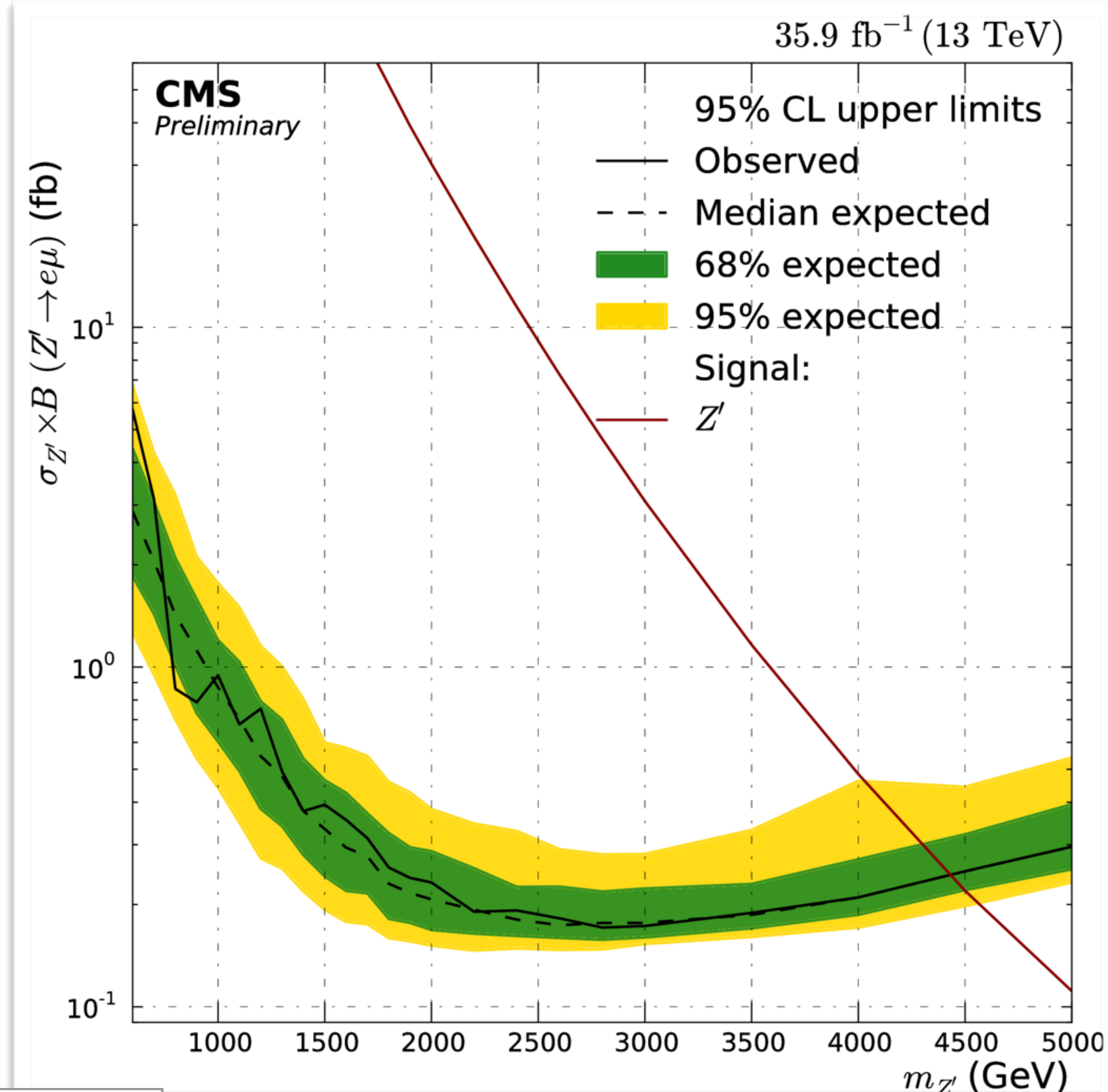
HIGH MASS eμ SEARCH (CMS)

EXO-16-058, **JHEP 04 (2018) 073**, arXiv 1802.01122

Z' in a LFV model

- Sequential Standard Model like Z'
- Z'→eμ decay allowed
- Width 3%





Z' excluded up to 4.4 TeV

$$\mathcal{L}_{Z' \to l_1 l_2} \propto \frac{g_{EW}}{2\cos\theta_W} \kappa_{ij} Z'_\mu \left[\frac{1}{2}\bar{l}_1 \gamma^\mu \gamma_5 l_2 - \left(\frac{1}{2} - 2\sin^2\theta_W\right) \bar{l}_1 \gamma^\mu l_2\right]$$

HIGH MASS $e\tau$ and $\mu\tau$ SEARCHES (ATLAS)

arxiv 1807.06573, **Phys.Rev.D 98 (2018) 9, 092008**

Less clean channels due to hadronic tau

More elaborate event selection, to control background

Events should have exactly two different-flavour leptons

  Veto events with additional electron, muon, hadronic-tau

Back-to-back: $\Delta\varphi(l1,l2) > 2.7$

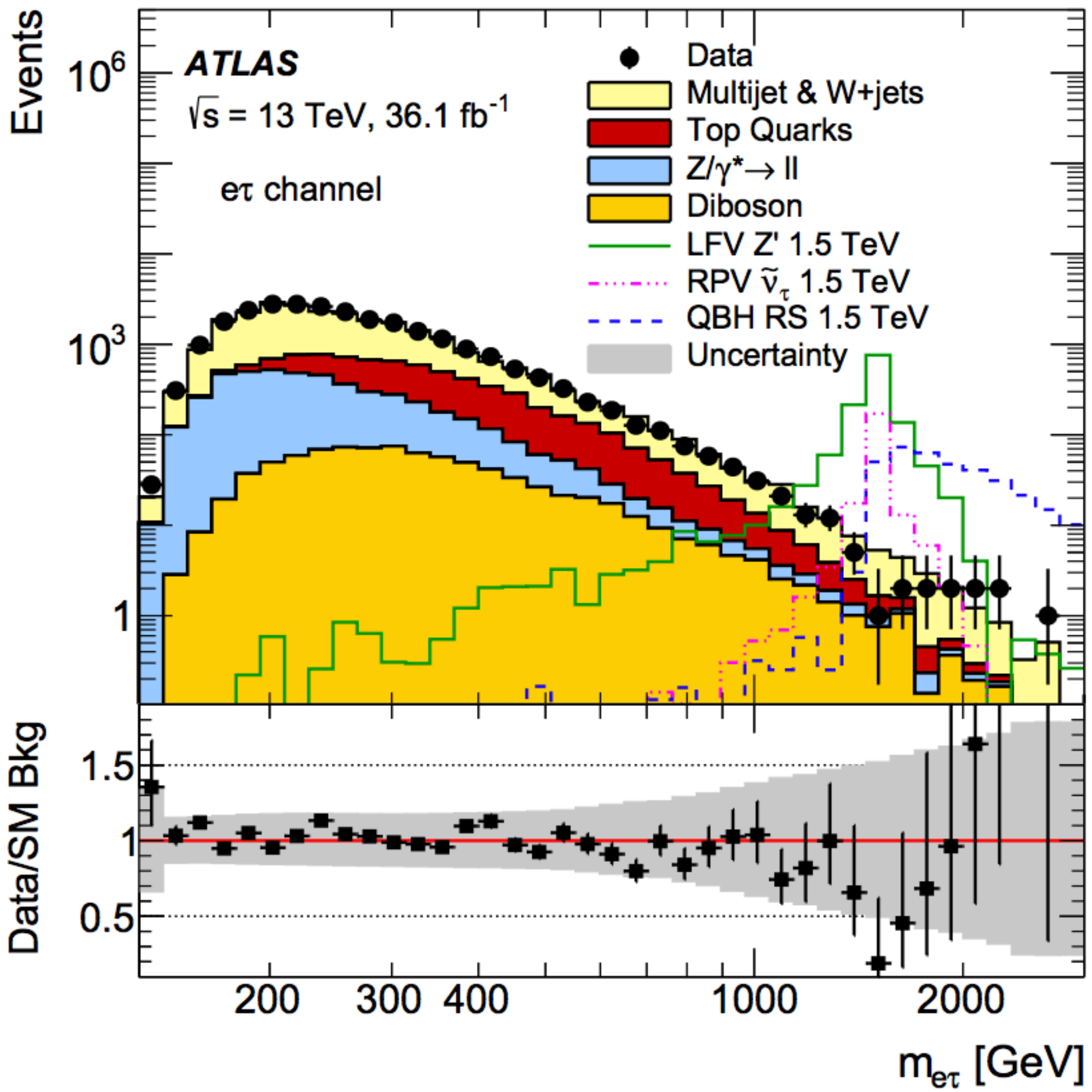
For high-pT hadronic-tau decay, neutrino and tau-jet are collinear.

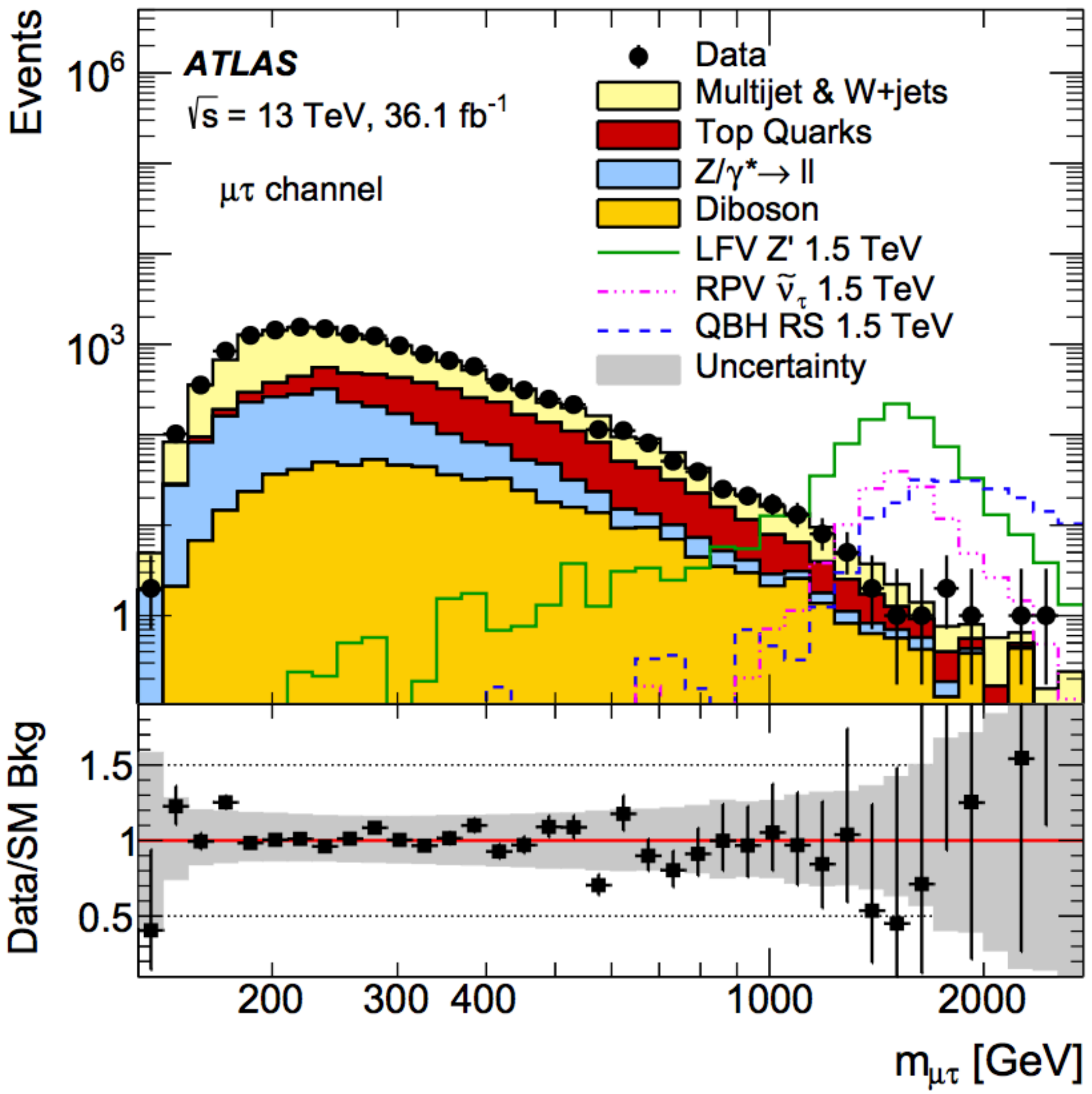
Neutrino p4 reconstructed from MET and the direction of the visible tau candidate.

Neutrino p4 added to visible tau p4: results in better mass resolution, better analysis sensitivity

HIGH MASS $e\tau$ and $\mu\tau$ SEARCHES (ATLAS)

arxiv 1807.06573, **Phys.Rev.D 98 (2018) 9, 092008**

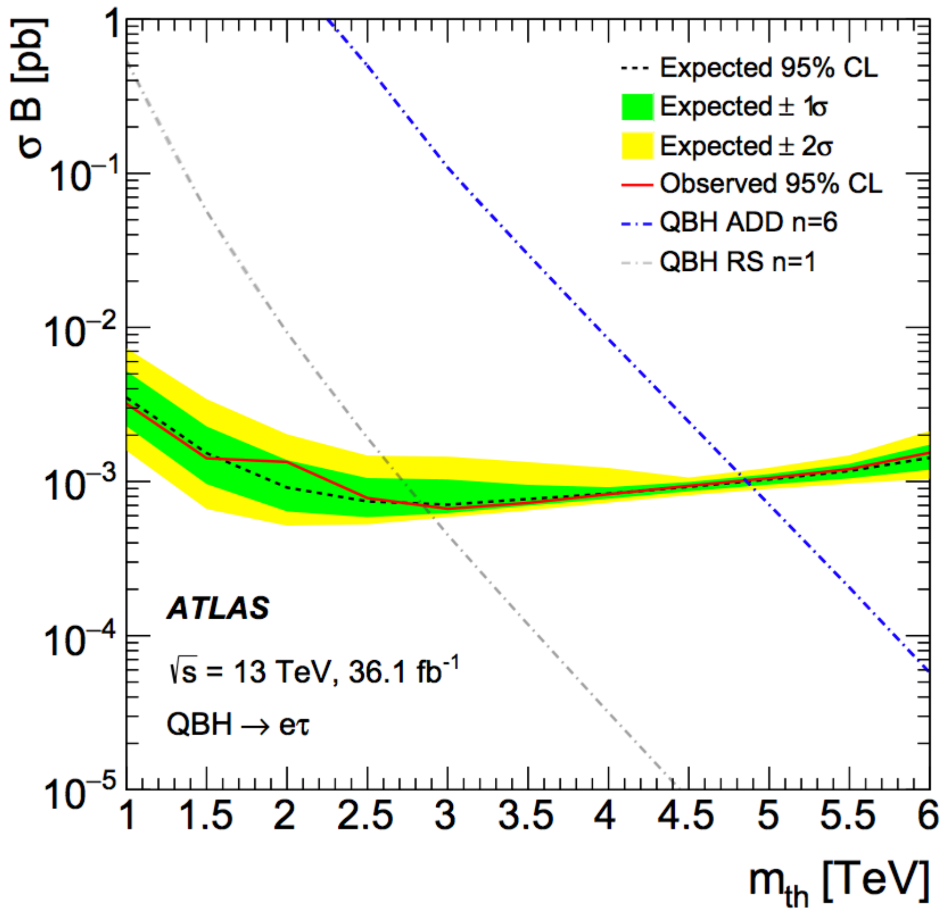


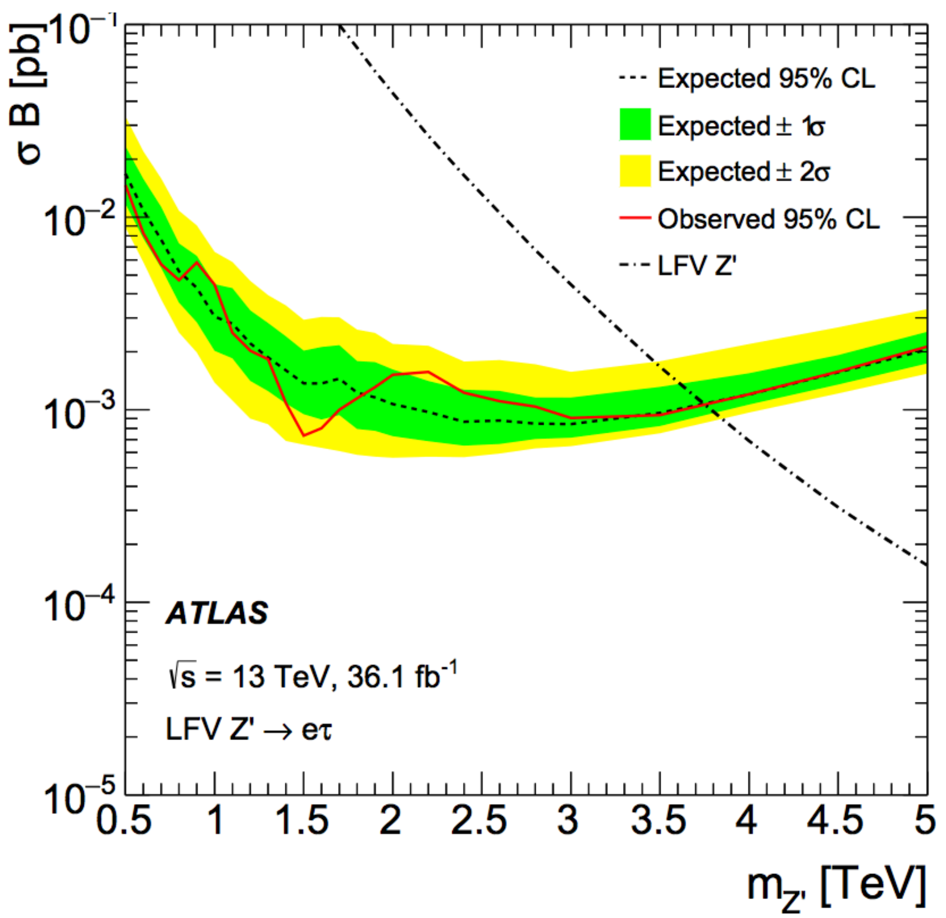


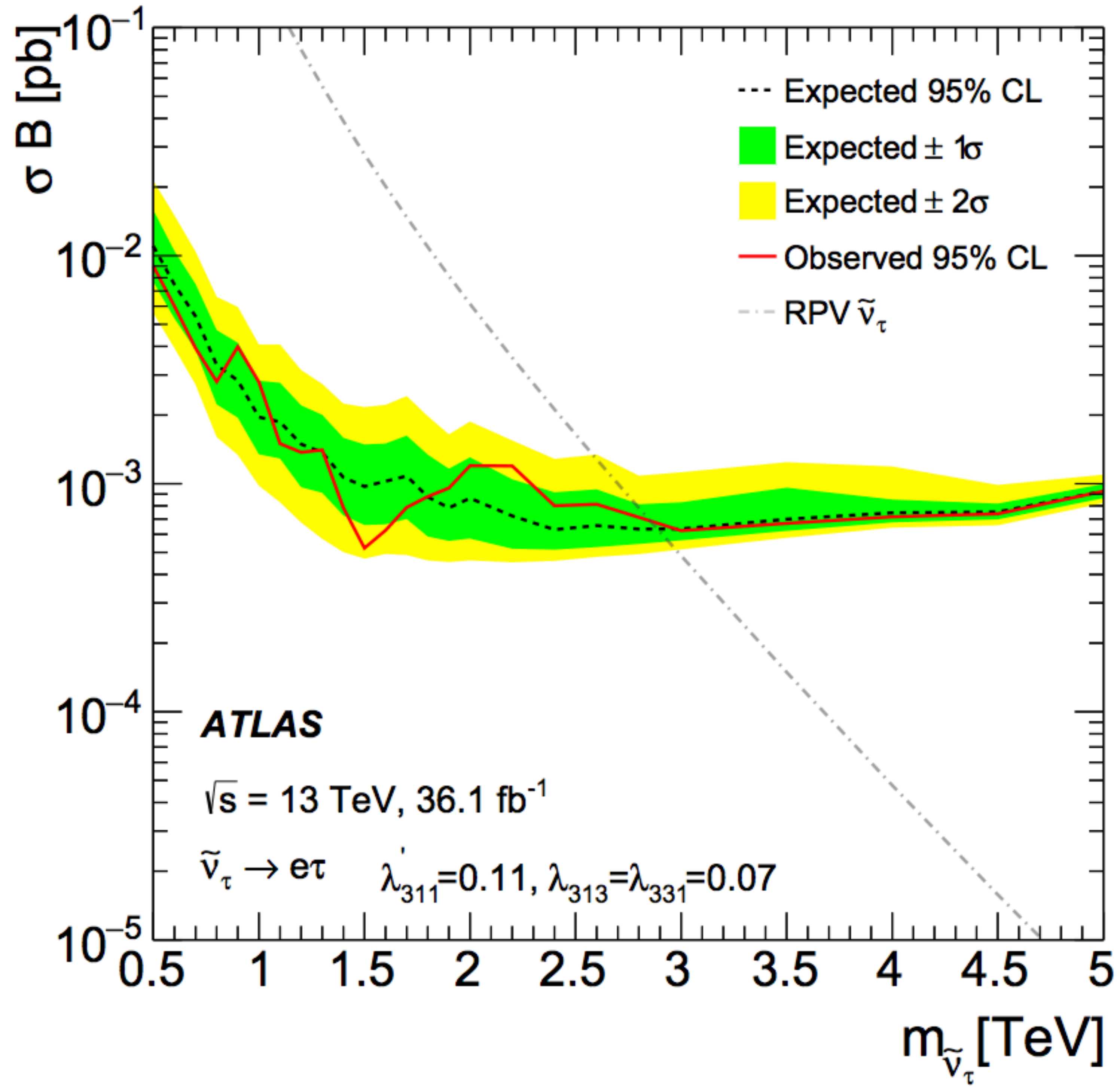
No significant excess

HIGH MASS eτ SEARCH: RESULTS (ATLAS)

arxiv 1807.06573, **Phys.Rev.D 98 (2018) 9, 092008**

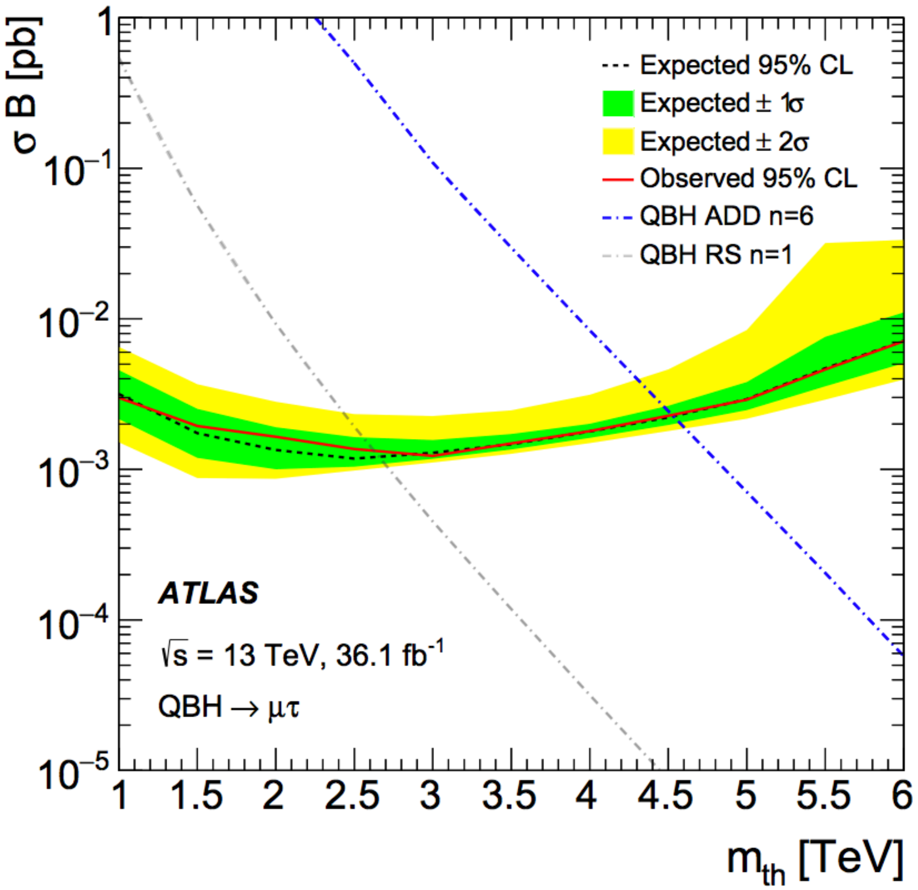


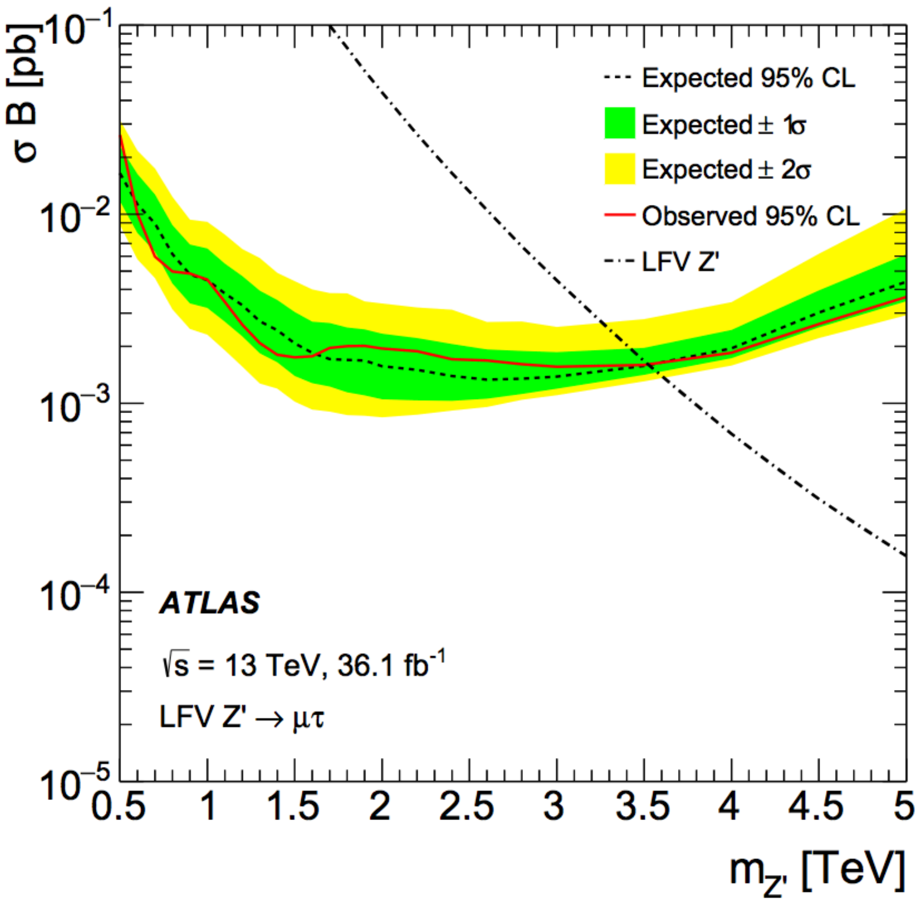


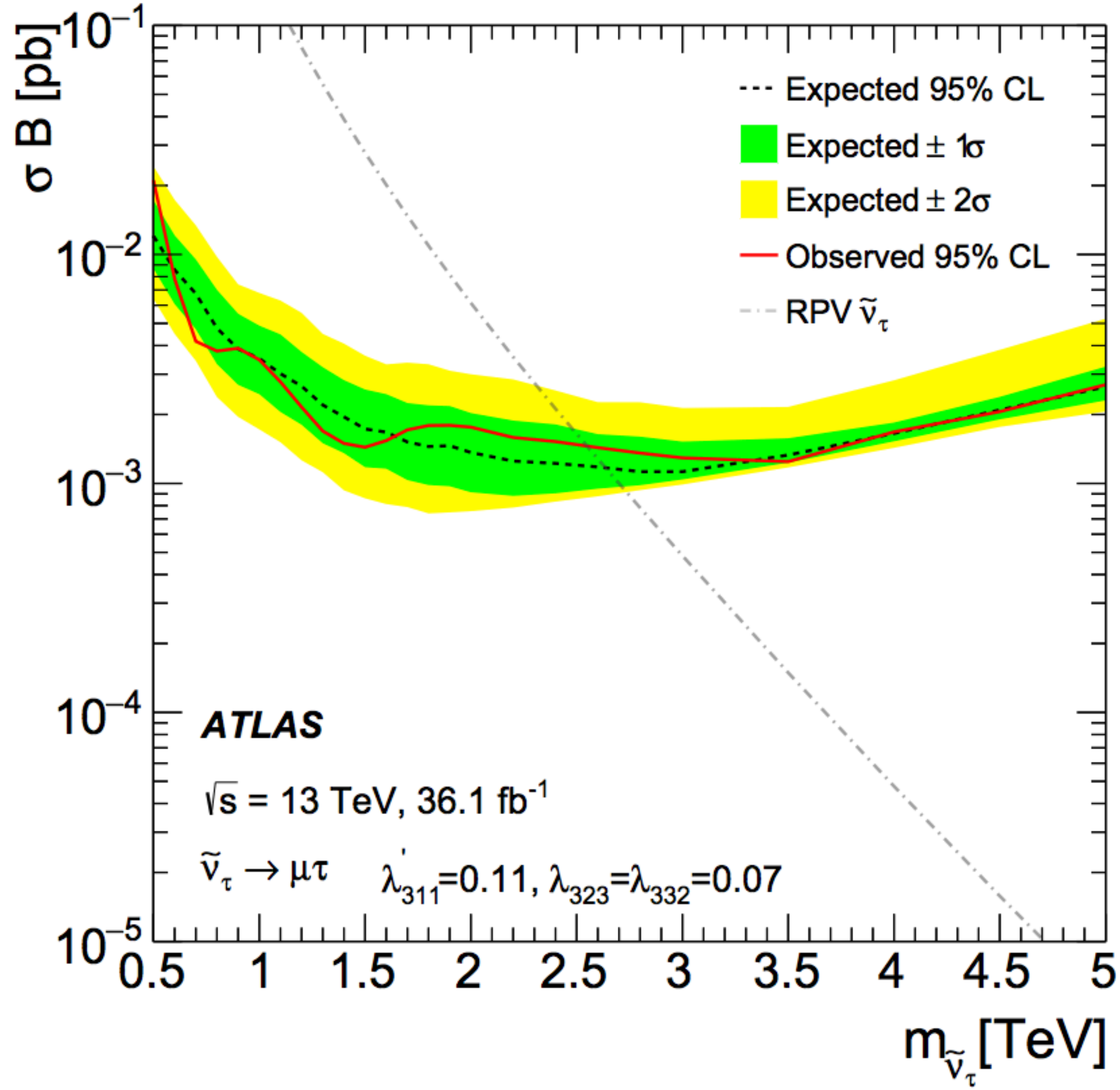


HIGH MASS μτ SEARCH: RESULTS (ATLAS)

arxiv 1807.06573, **Phys.Rev.D 98 (2018) 9, 092008**







Systematic uncertainties

eμ channel (CMS)

Dominant systematics: ttbar theory uncertainties (ttbar is also the dominant background)

e**τ** and μ**τ** channels (ATLAS)

Dominant systematics: PDF uncertainty

Other systematics include

Pile-up

Lepton efficiency due to trigger, identification, isolation

Lepton and jet energy scale and resolution

HEAVY FERMION SEARCH

EXO-17-006, arXiv 1802.01122, **PRL 119 (2017) 22, 221802**

Type-III seesaw model, aims to explain neutrino mass

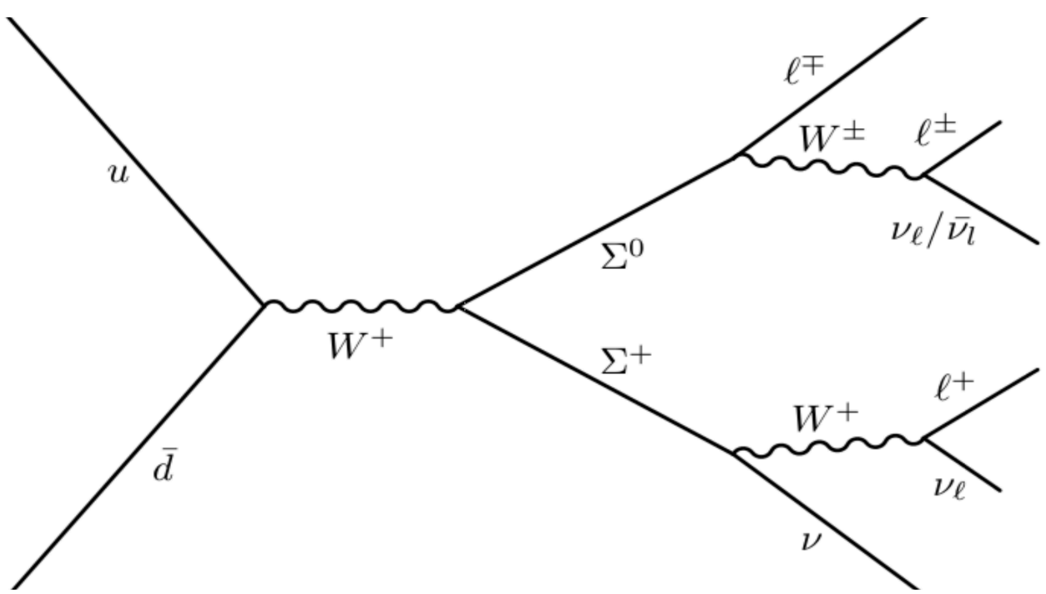
SU(2) triplet of heavy Dirac charged leptons Σ±, and a heavy Majorana neutral lepton Σ0

Pair-production of heavy fermions (Σ±Σ∓)(Σ±Σ0)

Heavy fermion → W/Z/H + lepton

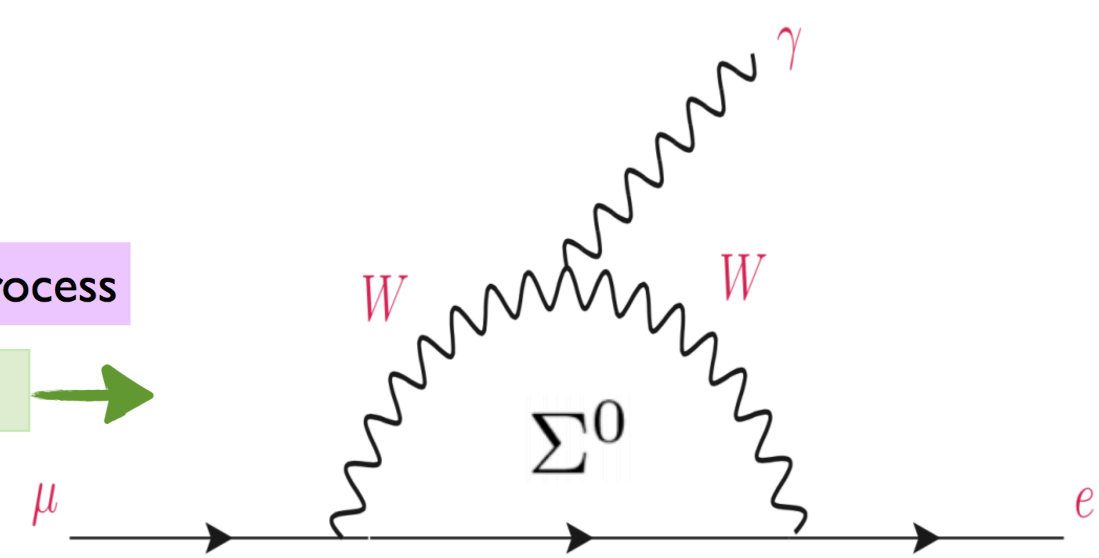
Σ± and Σ0 degenerate in mass

Σ → lepton decays flavor democratic



No LFV in this process

but leads to this



HEAVY FERMION SEARCH

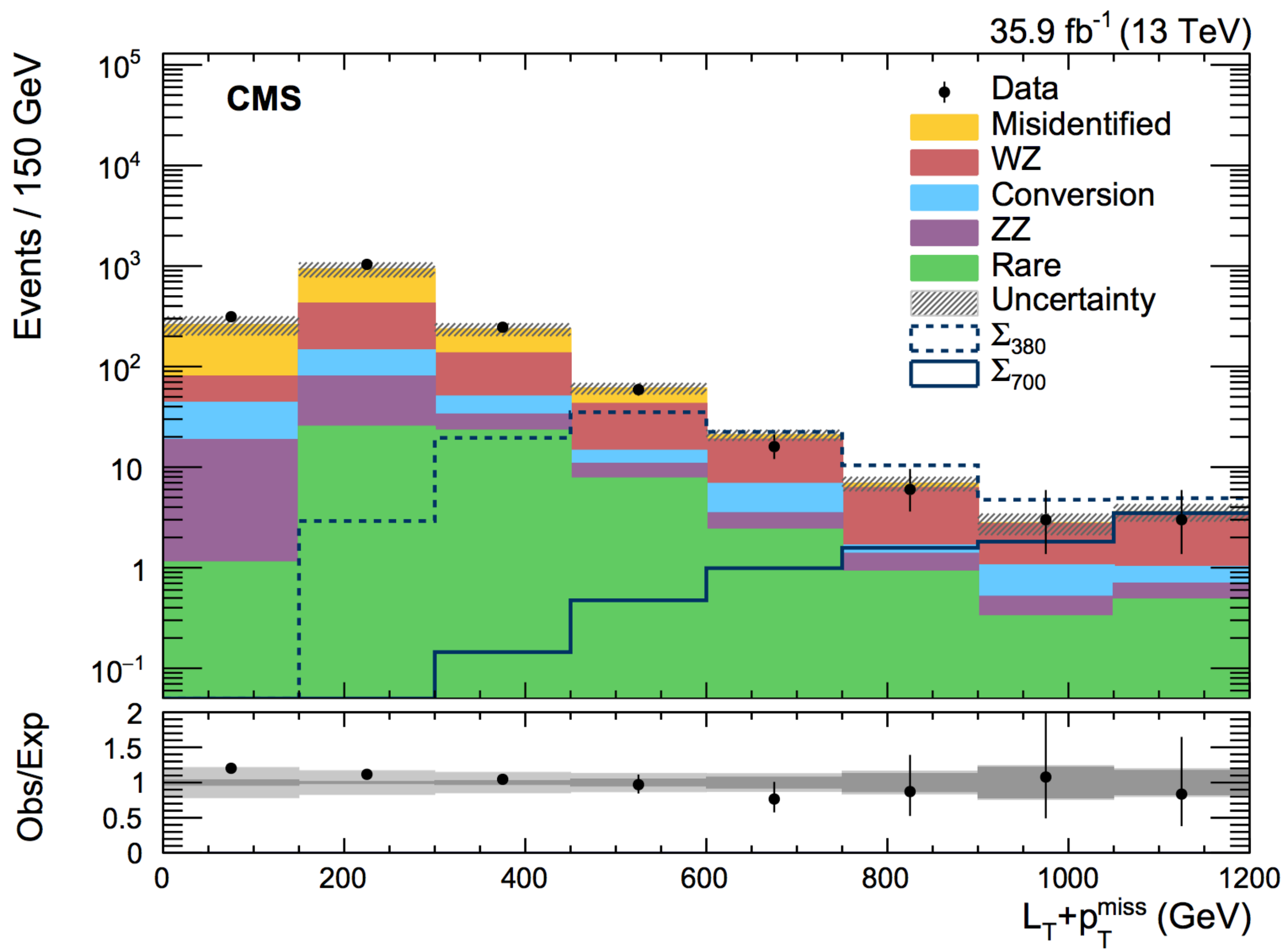
EXO-17-006, arXiv 1802.01122, **PRL 119 (2017) 22, 221802**

Experimental Signature

- At least 3 isolated leptons

6 event-categories based on

- Number of leptons in final state (eg. 3, ≥4)
- OSSF lepton-pair
  - number:0,1 or 2
  - Mll : on / below / above Z

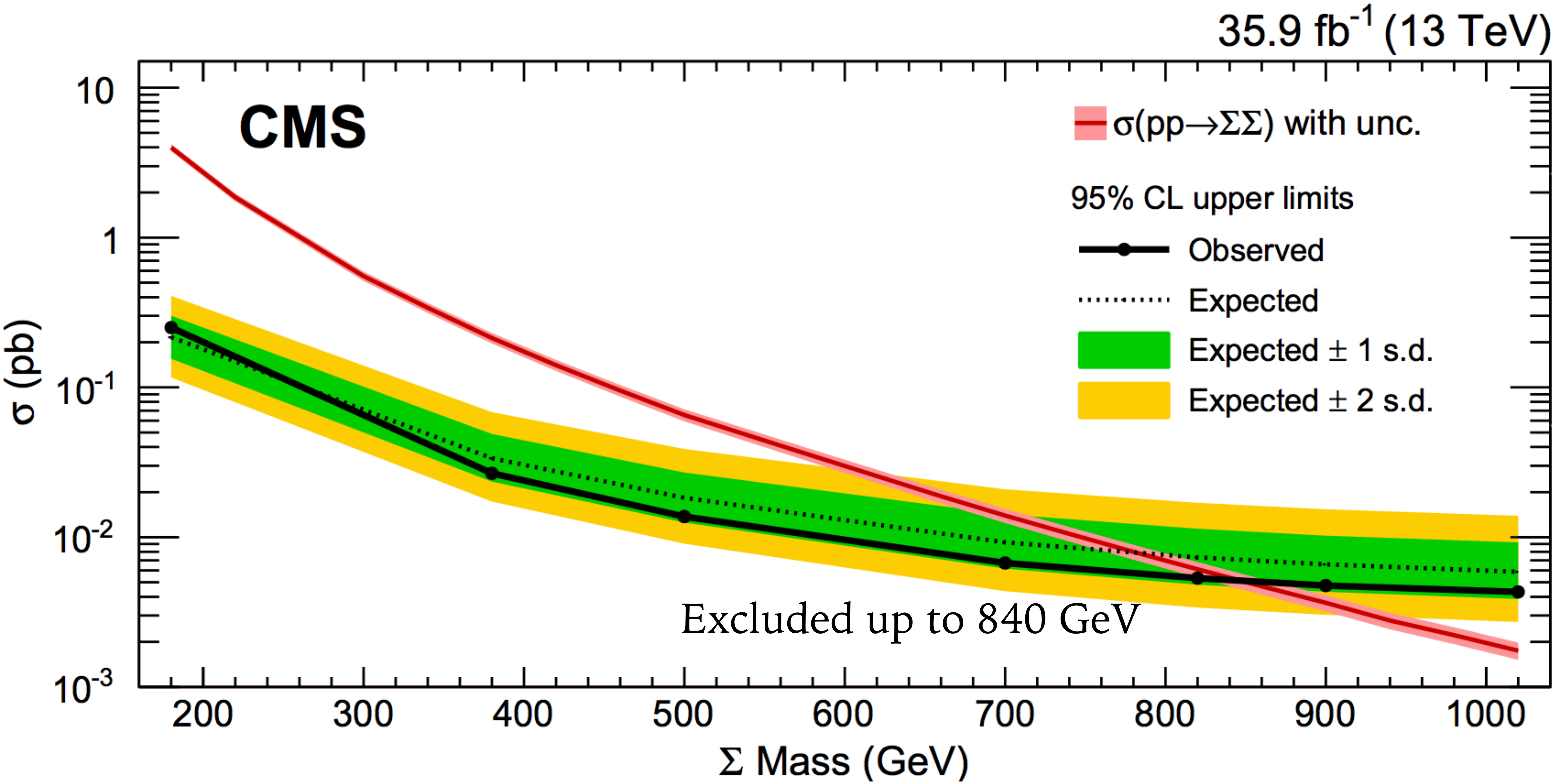


No significant excess

27 different production and decay processes considered

HEAVY FERMION SEARCH

EXO-17-006, arXiv 1802.01122, **PRL 119 (2017) 22, 221802**

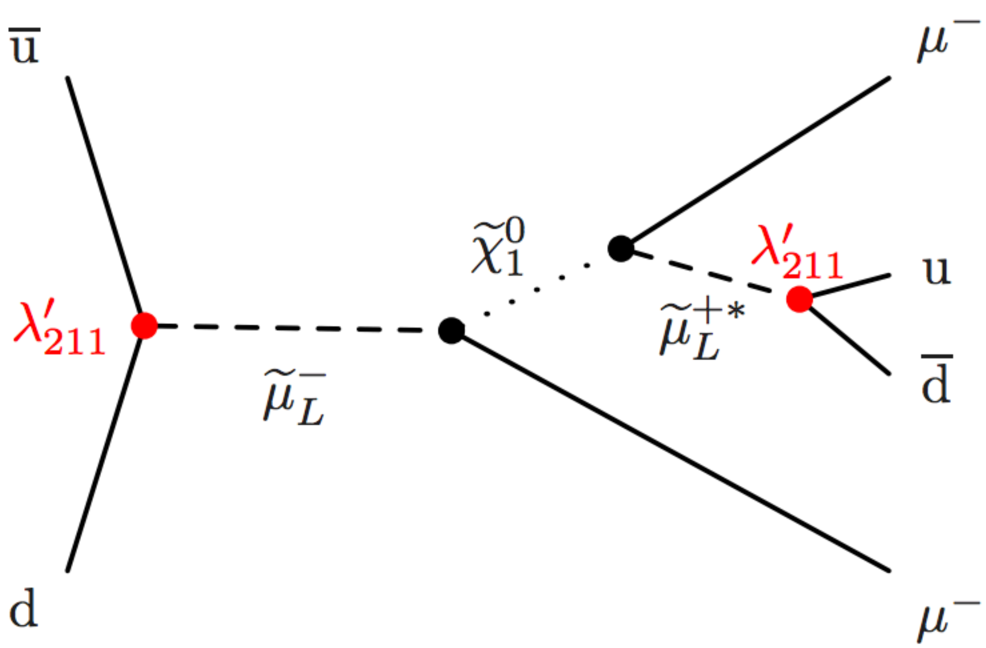


Model assumption: flavor-democratic scenario, ie, equal branching fractions to each lepton flavor

LEPTON NUMBER VIOLATION

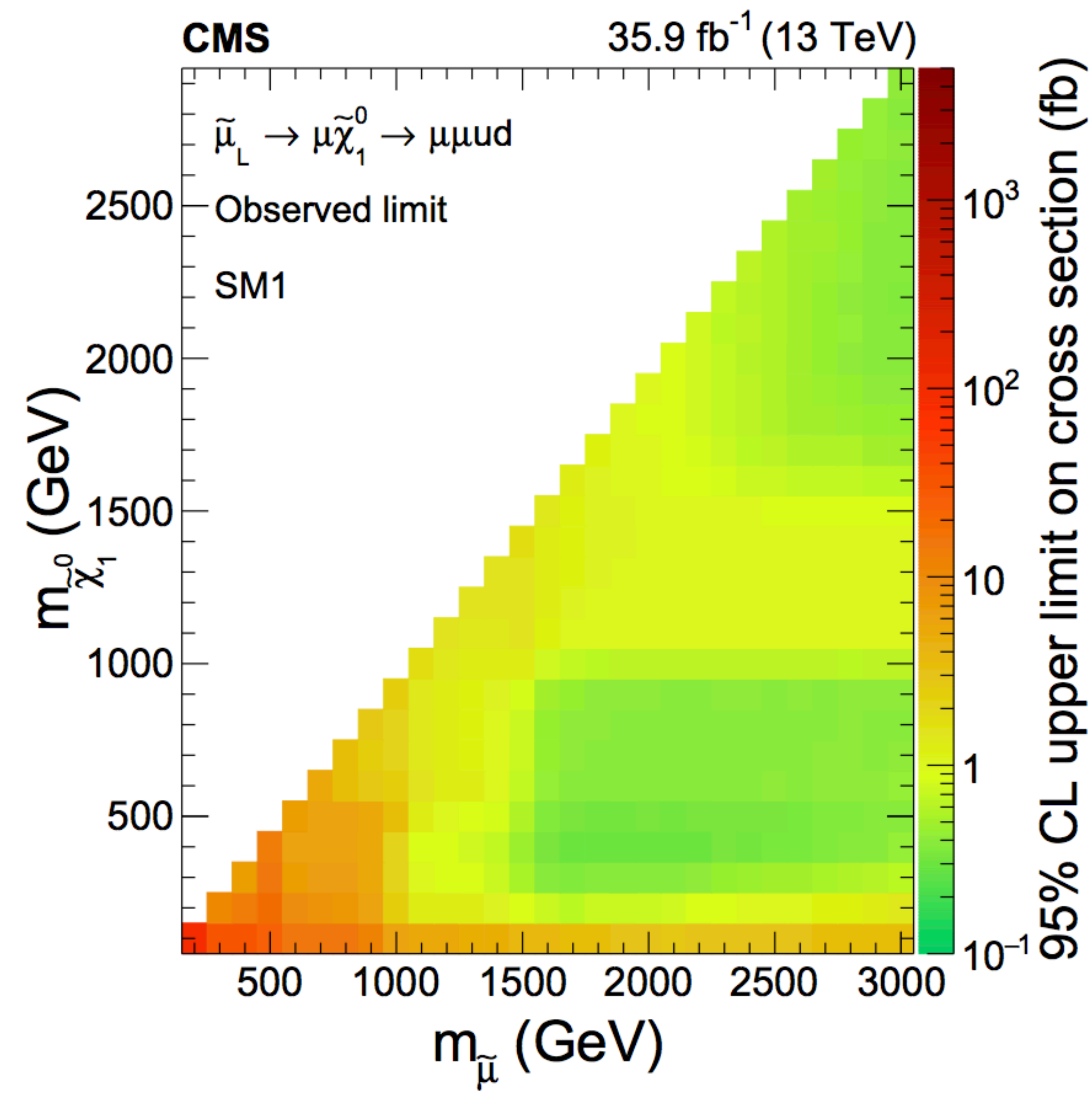
- RPV SUSY can lead to LNV (depends on model assumptions)
- One example:

CMS-SUS-17-008, arXiv 1811.09760, **EPJC 79 (2019) 4, 305**



Resonant production of smuon in RPV SUSY

Same-sign dimuon events, with at least 2 jets

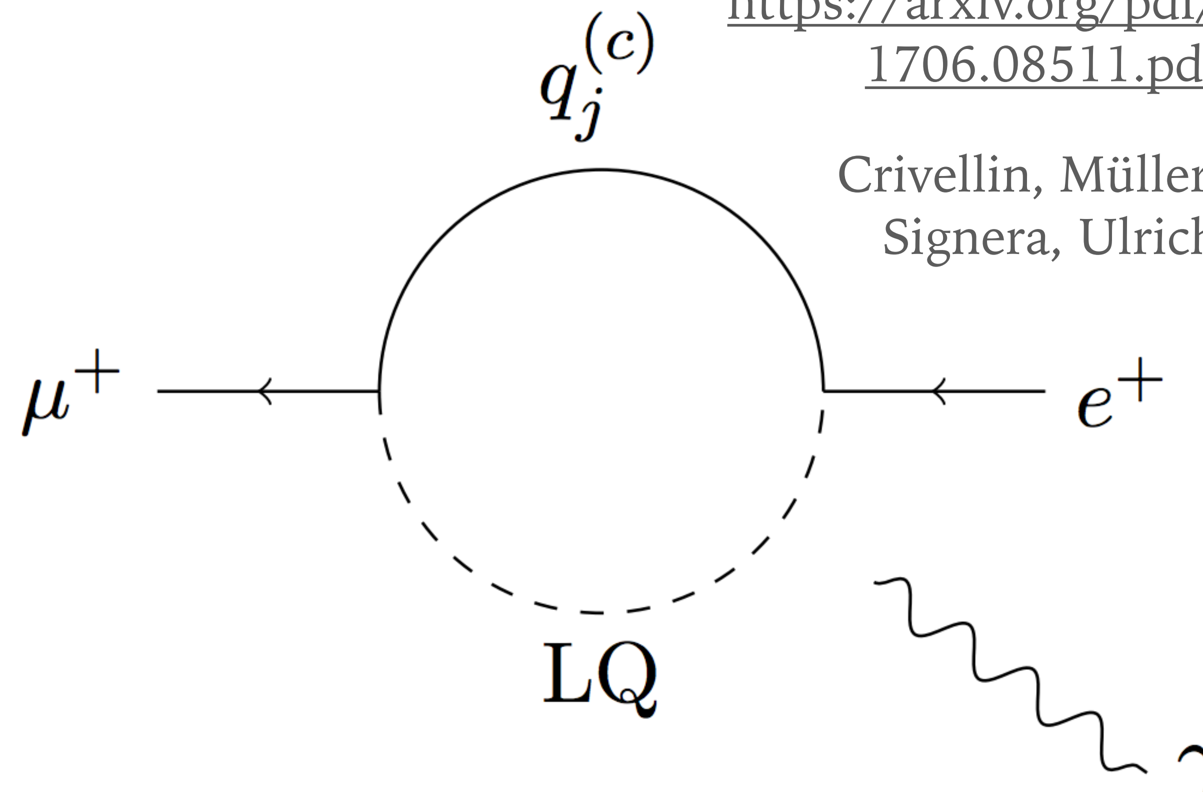


FEW WORDS ABOUT LEPTOQUARKS

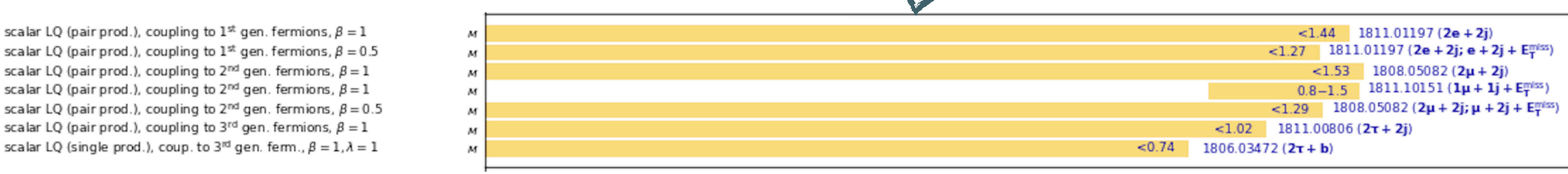
- Leptoquarks could lead to LFV and LFUV
- Increased interest in leptoquark searches due to B-anomalies
- LQ LFV models generally have very low cross-section, or allowed LQ mass very high, so current searches focus on generation specific LQs
- Pair production/ single production
- Mass exclusion limit at the ballpark of 1 TeV (depends on model)

https://arxiv.org/pdf/1706.08511.pdf

Crivellin, Müller, Signera, Ulrich



Summary of CMS LQ searches



SUMMARY AND OUTLOOK

Charged LFV is an extremely clean and sensitive probe for physics beyond the Standard Model

Experimentally and theoretically rich

Strong portfolio of charged LFV searches in CMS and ATLAS

Presented some searches

- Unfortunately no sign of new physics yet
- Stay tuned for more results to come

EXTRA SLIDES